

EVALUATION OF INDUSTRIAL TECHNIQUES, MAINTENANCE AND  
IMPROVEMENTS OF PERFORMANCE RATING IN TIME STUDY

by

HENRY KIJOWSKI

B.S., Aeronautical Engr., Tri-State College, 1945  
B.S., Mechanical Engr., Tri-State College, 1947

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of performance, the so-called "normal performance." No definition of "normal" being ever given, some people considered "normal" as a kind of speed for nonincentive workers. Others took it for granted that "normal" was the speed to be maintained without "taking a rest."

"Today 'normal pace' is defined as the 'effective' rate of performance of a conscientious, self-paced, qualified employee when working neither fast nor slow and giving due consideration to the physical, mental, or visual requirements of the specific job."(6)

A definition of performance rating is needed. Performance rating is that process in which the time study analyst compares the performance (speed or tempo) of the operator under observation with the observer's own concept of normal performance. Rating is a matter of judgment on the part of the time study analyst, and unfortunately, there is no way to establish a time standard for an operation without having the judgment of the analyst enter into the process.

At this point it is necessary to mention that extreme confusion exists in the terminology with respect to the various rating systems in use. For example, leveling is a term used by some as an alternate name for the Westinghouse system, by others as a general term for the process of rating. Pace rating is referred to by some as effort rating or performance rating. Performance rating is sometimes called effort rating. Leveling is sometimes referred to as skill and effort rating. As with a number of other topics in this field, a person must clear the terminology air before he can intelligently discuss the subject of rating with another.

Several means are employed to help the time-study observer improve his accuracy and consistency in rating. Spot-rating practice is designed

to provide frequent check of the observer's judgment. In using spot rating, a supervisor may accompany one or more of his time-study men about the plant and have each man independently rate various operators. Ratings are recorded and then compared with the supervisor and within the group to reveal the degree of consistency among the raters. Where deviations too great to be acceptable are occurring, the actual operation may be looked at in more detail while the time-study men advance the reasons for their ratings. This contributes to a better understanding of what to look for and also helps to build the concept of a normal performance.

Specific instructions can be given in the form of exactly what to look for in observing the performance. For example, the observer may be misled in his judgment when an operator performs a long-hand movement very rapidly but takes a longer time than normal to perform the next positioning operation because of the previous rapid movement. Finger dexterity, certainty of movements, and a blending of movements are indications of superior performance. Pointing out these differences between individuals and assessing their effect on productivity is helpful training to the practicing time-study men.

Films depicting different operations performed at various levels are receiving considerable attention. Several films have been prepared which provide standards by which the individual may assess and thereby compare his judgment of the performances shown with the pooled judgment of experienced time-study men who have rated the film. Practice rating or leveling in real-life situations is desirable since that is where the work will eventually be done—out in the shop. It is found that practice in rating filmed operations is helpful to time-study men. This is

particularly true when an operation is reviewed following the original rating. In the review, the small differences between operator movements may be examined in detail and the reasons for the differences in output pointed out so that they will be recognized in the future. Regardless of the device used, it is well established that it is necessary to train the beginner carefully and to continue to train him as long as he is asked to do performance rating. Such a planned program will yield good results in the form of more accurate and more consistent time standards.

A study of 100 companies shows that 63% use motion picture films as a means of training and as a means of checking the rating ability of their time study analysts.

Finally all commonly employed time study rating procedures can be placed into two main groups.

1. Mathematical Rating
2. Judgment Rating

Synthetic leveling would fall in the first group and speed rating would fall in the second group.

## OBJECTIVE RATING

The objective rating system purports to produce a more reliable time study procedure due to the realization that the difficulty of the job and its effect on maximum possible pace does not need to be judged but may be reduced to tabular form as a function of strength required, members of the body used, degree of dexterity, and others. Thus, a two-step rating procedure is produced and consists of the following steps:

1. The rating of observed pace against an objective pace-standard, which is the same for all jobs. In this rating, no attention whatever is paid to job difficulty and its limiting effect on possible pace; hence, a single pace-standard may be used instead of a multiplicity of mental concepts.

2. The use of a "difficulty" adjustment, consisting of a percentage increment, added after the application of the numerical appraisal from step 1 has been used to adjust the original observed data. This percentage increment is to be taken from experimentally determined tables of the effect of various observable factors that control the exertion required at a given pace.

In practice the time study man, in performing step 1 of the objective rating procedure, may do one of the following:

- A. Compare the observed job with his concept of the scale of standard pace as obtained by considerable exposure to the multi-image or step films.

- B. Compare a film of the observed pace with the multi-image films with simultaneous projection by two projectors.

Step films are films showing step-by-step deviations from standard

pace on the one job, so as to establish markings on the scale of pace and to facilitate the rating. Such films are commonly made with the frames divided into different areas, each area showing a different pace, so that a group of steps may be projected simultaneously. Groups of step films are called multi-image films. Multi-image films should be viewed everyday by time-study men in order to keep their memories fresh as to the different work paces.

In either of the above cases the time study man must only judge whether the job being studied (actual performance or film of performance) is being performed at a pace (rate of activity) equal to any one of the steps on the multi-image step film (or single-image step films), or between any two of the steps, and then assign a rating as indicated by the predetermined values of the steps. He pays absolutely no attention to the limiting effect of job difficulty on the possible pace for the task. The subjective inference required in performing step 1 of conventional rating has been eliminated, thus offering a more reasonable chance of obtaining the requisite accuracy in time study.

After the time study observer has performed step 1 (for pacing) he is then ready to perform step 2 of the objective rating procedure. It is obvious that all jobs can not be performed at the standard pace, since practically all will be more difficult than the job with which standard pace is established, and further, some jobs will be more difficult than others. Some tasks, for instance, will involve heavier parts, or closer visual work. These job differences place different limits on the pace possible on each job with a fixed rate of exertion relative to the maximum possible on the job, and these have been objectively evaluated. The evaluation is accomplished by determining the

various factors that make for difficulty in the job, their effect evaluated, and a "difficulty adjustment" in percentage terms utilized.

The factors that affect pace were obtained through experimentation or practical evidence and are listed as follows:

1. Percent of body members involved in the element.
2. Foot pedals used during the element.
3. Extent of bimanual effort needed to perform the element.
4. Eye-hand co-ordination required to perform the element.
5. Handling or sensory requirement of the element.
6. Resistance that must be overcome in performing the element—that is, thrust on levers or weight lifted.

It is these "difficulty adjustments" which require further development since only certain points in some of the scales were determined and the rest of the scales for these factors had been set in "apparent" correct proportion.

It must be remembered that the total difficulty adjustment for an element will be the simple sum of all the appropriate values from the scales for all the factors. All adjustments are indicated as positive increments of time above the time required at the standard pace.

Table 1. Adjustments for job difficulty as used in objective rating.(4)

Category :		Reference :		:	%
No.	Description :	letter :	Condition	:	Adjustment
1	Element or member of body used	A	Fingers used loosely		0
		B	Wrist and fingers		1
		C	Elbow, wrist and fingers		2
		D	Arms, etc.		5
		E	Trunk, etc.		8
		E2	Lift with legs from floor		10



Table 1 (continued)

Category :		Reference :		%
No. :	Description :	letter :	Condition	Adjustment
2	Foot pedal	F	No pedals or one pedal with fulcrum under foot	0
		G	Pedal or pedals with fulcrum outside of foot	5
3	Bimanualness	H	Hands help each other or alternate	0
		H2	Hands work simultaneously doing the same work on duplicate parts	18
4	Eye-hand coordination	I	Rough work, mainly feel	0
		J	Moderate vision	2
		K	Constant but not close	4
		L	Watchful, fairly close	7
		M	Within 1/64 inch	10
5	Handling requirements	N	Can be handled roughly	0
		O	Only gross control	1
		P	Must be controlled, but may be squeezed	2
		Q	Handle carefully	3
		R	Fragile	5
6	Weight		Identify by the letter W followed by actual weight or resistance. See Table 2.	

Table 2. Adjustments due to weight as used in objective rating.(4)

Weight in pounds	% adjustment arm lift	% adjustment leg lift
1	2	1
2	5	1
3	6	1
4	10	2
5	13	3
6	15	3
7	17	4
8	19	5
9	20	6
10	22	7
11	24	8
12	25	9
13	27	10
14	28	10
etc.	etc.	etc.

The following example illustrates how the normal time for an element is determined using this system of rating. If the selected time for an element is 0.26 minute, the pace rating is 95%, and if the sum of all secondary adjustments amounts to 20%, then the normal time will be 0.297 minute ( $0.26 \times 0.95 \times 1.20$ ). (8)

M. E. Mundel has done extensive and intensive work to develop the "Objective Rating" system in order to achieve what he calls a realistic approach for providing a better system of measurement of rating. The claim is that although the ratings may still have errors, the errors will be much reduced by comparison with other systems. And that the errors result from a chance-cause system rather than being biased by a "game." In those cases requiring considerable precision, averaging ratings will yield a value approaching a true value rather than a biased value. (2)

Objective rating is intended to satisfy the following management requirements:

1. A uniform concept of "standard" among the time study men.
2. A reduction in rating error.
3. A demonstrable yardstick of "standard."
4. A basis for maintaining a concept of "standard" in subsequent years and with eventual changes in the time study staff. (8)

## SYNTHETIC LEVELING

Synthetic leveling attempts to do what Objective Rating does. To provide a rating that is not influenced by human judgment or bias, and at the same time to produce consistent results. The "Synthetic Leveling" system was developed by R. L. Morrow. In essence this leveling procedure determines a performance factor for representative effort elements of the work cycle by comparing actual elemental observed times to those times constructed through the medium of fundamental motion data. Thus, the performance factor may be expressed thusly:(6)

$$P = \frac{F}{O}$$

where

P = performance or leveling factor

F = fundamental motion time

O = observed mean elemental time for the same elements as used in F.

The factor thus determined would then be applied to the remainder of the manually controlled elements comprising the study.

The applications of synthetic leveling given here are based on the data by Barnes and Engstrom as shown in the following two tables:

Table 3. Classification of work conditions.

(7)

		Division			
		M(3F): L(H): S(2F): V.L.(2H)			
Element	Description	Class			
Get conditions No. 1	Very best facility possible, due to design or prepositioning of object for grasp; no interference or hinderence with grasp by other objects. Size of object need not be considered.	1	1	1	1
Get conditions No. 2	Grasp is easily made, but parts may be in quantities requiring some selection of a single part. No untangling or difficult separation.	1	2	2	2
Get conditions No. 3	The design or finish of parts, prevents ready grasping, parts may tangle, nest together, or be packed with separators.	2	3	3	4
Place conditions No. 1	Place objects where positioning is normally little more than releasing the object or moving is slightly on the work place.	1	1	1	2
Place conditions No. 2	Place objects where positioning consists of some definite location, simple, open nests or fixtures. Loose tolerances.	1	2	2	3
Place conditions No. 3	Place objects where positioning is in difficult or complicated location, assemblies or fixtures requiring positioning of parts with respect to two points or locations in two directions.	2	3	3	5
Place conditions No. 4	Same as condition No. 3 but close tolerances, more points of location, greater care in handling or application of force.	3	4	4	6

Table 3 (continued)

Meaning of Division symbols:

- M(3F) - Medium size piece; three fingers and thumb control
- L(H) - Large piece; extended hand control
- S(2F) - Small piece; two fingers and thumb control
- V.L.(2H) - Very large piece; two hand control

The element "get" includes the elements of motion "transport empty" and "grasp."

The element "place" includes the elements "transport loaded," "position" and "release load."

Table 4. Standard times for "get" and "place."

(7)

Class	Maximum Distance (inches)	Time Values (Minutes)		
		G and P	G2	P2
1	12	.007	.010	.011
2	24	.013	.017	.020
3	24	.021	.028	.031
4	24	.026	—	.039
5	24	.036	—	—
6	24	.048	—	—

For transport empty and transport loaded distances over 24 in. and up to 36 in. add 0.12 minute.

When time values for all elements in an operation can be obtained from tables 3 and 4, the standard for the entire operation may be obtained directly. Instances may arise where time values are not available from tables or the operation may have too many elements.

As an illustration of the application of synthetic rating, assume there is a job consisting of 12 elements and where fundamental motion time is available for only 2 elements.

Element No.	1	2
Fundamental motion time	.096	.278
Observed average time	.080	.22
Performance factor	120%	126%

$$P_1 = \frac{.096}{.080} \times 100 = 120\%$$

$$P_2 = \frac{.278}{.22} \times 100 = 126\%$$

The mean of 120% and 126% would be 123% and this is the factor used for rating all 12 of the effort elements. From this it can readily be seen that synthetic performance rating is a sampling technique.

Actually, all experienced time study men unconsciously follow the synthetic rating procedure to some extent. The time study man's mind is full of benchmarks that have been established from past experience on similar work. These benchmarks and many others, when compared to actual performance, certainly influence and even determine the rating factor given the operator.(10)

Perhaps one of the major objections to the application of the synthetic leveling procedure is the time required to construct a left- and right-hand chart of the elements selected for the establishment of basic motion times.(9) In rebuttal to this objection, it must be remembered that this particular leveling technique is essentially a sampling technique and it would not be necessary to construct a left- and right-hand chart for all elements. Based on previous element quantity per job—2, 3, 4 or n elements could be random selected to obtain the fundamental motion

times to calculate the performance factor. Then it again may be desirable to establish a standard for the entire job synthetically. This would eliminate the laborious task of recording elemental times, making subtractions, determining the normal time synthetically for several elements so as to arrive at a performance factor, and applying the performance factor. Along this line, an alignment chart has been designed to aid the time study man to arrive at synthetic values rapidly and accurately.

Synthetic leveling as now outlined is not a finished procedure, it should be regarded as a method which, by further development, has great practical use and general application. Research is mostly needed in defining and limiting the applications.

The same leveling or rating factor may not apply to all elements in the study. However, upon analysis of the causes of variations in operator's performance level, the problem of taking these variations into account does not become too serious. If one part of the operation is more difficult to perform than the rest, the time standard used for comparison will be greater and would undoubtedly adequately allow for the increased difficulty.(6)

Synthetic leveling is a mathematical or sampling method and the accuracy and reliability of results are based on well-established statistical procedure. True, there are limitations to the application of sampling methods. However, these limitations have not been serious enough to prevent wide application of sampling methods with satisfactory results.

In this method of leveling it is not essential to have data for all elements of an operation being analyzed. This fact is a definite advantage and enables a much wider application to be made of the method.

However, synthetic leveling should be used only by the highly trained and experienced engineer.(7)

William Gomberg's view is that this method depends upon two assumptions that are not valid and that is, (1) there is a uniform relationship in the speed of the different elements to the speed of the over-all cycle and (2) the fundamental standard times for these known elements are based on the presupposition that the elements of which a job is composed make up an additive set, that is, that the time values assigned the elements are independent of the position or sequence in which they appear.(2)



## WESTINGHOUSE SYSTEM

One of the oldest and very widely used systems of rating is the one developed at the Westinghouse Electric Corporation and was originally published in 1927. The need for full understanding and adequate training in the use of the technique in order to get consistent and accurate results, is strongly stressed.

Four factors are given as constituting the important factors which determine the rate of production that an operator achieves. These four factors are skill, effort, conditions and consistency. The first two of these are by far the most important. Each of the four elements carries a somewhat special or limited meaning. It is important that these meanings be understood prior to the application of the technique.(6)

Skill is defined as "proficiency at following a given method" and can be further explained by relating it to craftsmanship, demonstrated by proper co-ordination of mind and hands. The skill of an operator is determined by his experience and inherent aptitudes such as natural co-ordination and rhythm. Practice will tend to develop skill, but it cannot entirely compensate for deficiencies in natural aptitude.

A person's skill increases on a given operation over a period of time because increased familiarity with the work brings speed, smoothness of motions, and freedom from hesitation and false moves. A decrease in skill is usually caused by impairment of ability brought about by physical or psychological factors such as failing eyesight, failing reflexes, and loss of muscular strength or co-ordination. From this, it can readily be appreciated that a person's skill can vary from job to job and even from

operation to operation on a given job.(9)

According to this system of leveling or rating, there are six degrees or classes of skill within which an operator can perform that represent an acceptable proficiency for evaluation. These are poor, fair, average, good, excellent and superskill. The skill displayed by the operator is evaluated by the observer and rated in one of these six classes.(10) This evaluation enables an observer to be consistent within less than plus or minus 5%. The skill rating is then translated into its equivalent percentage value, which ranges from plus 15 per cent for superskill to minus 22 per cent for poor skill. This percentage is then combined algebraically with the ratings for effort, conditions and consistency to arrive at the final leveling, or performance rating factor.

Following is a table showing the rating for different levels of skill:

Table 5. Skill.

(5)		
+0.15	A1	Superskill
+0.13	A2	
+0.11	B1	Excellent
+0.08	B2	
+0.06	C1	Good
+0.03	C2	
0.00	D	Average
-0.05	E1	Fair
-0.10	E2	
-0.16	F1	Poor
-0.22	F2	

Effort, according to this rating method, is defined as a "demonstration

of the will to work effectively." Effort is not related to the amount of foot pounds of work exerted during a given period, but rather to the zest or energy with which the task at hand is undertaken. Effort is controllable at all times by the operator.

Effort ranges from the point where pure idleness ends to an excessive working pace which is unwise to maintain. For industrial purposes, however, the range is reduced in extent by eliminating from consideration the lower levels of effort. The useful range is divided into six general classifications: poor, fair, average, good, excellent, and excessive. Effort is influenced by the operator's physical and mental conditions, fatigue playing an important part. Following is a table showing the rating factors for different degrees of effort.(9)

Table 6. Effort.

(5)		
+0.13	A1	Excessive
+0.12	A2	
+0.10	B1	Excellent
+0.08	B2	
+0.05	C1	Good
+0.02	C2	
0.00	D	Average
-0.04	E1	Fair
-0.08	E2	
-0.12	F1	Poor
-0.17	F2	

The "conditions" referred to in this performance rating procedure are those which affect the operator and not the operation. In most instances, conditions will be rated normal or average, as conditions

are evaluated in comparison with the way in which they customarily are found at the work station. Some of the elements that would affect the working conditions are temperature, ventilation, light and noise. Thus, if the temperature at a given work station was 60°F. whereas it customarily was maintained at 68° to 74° F., the conditions would be rated lower than normal. Those conditions which affect the operation, such as poor conditions of tools, poor conditions of materials, etc., would not be considered. Six general classes of conditions have been enumerated with values from plus 6 per cent to minus 7 per cent. "General-state" conditions are listed as ideal, excellent, good, average, fair, and poor. The same methods of evaluation apply to comparisons between plants.

Following is a table for performance rating due to conditions.

Table 7. Conditions.

(5)

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+0.06	A	Ideal
+0.04	B	Excellent
+0.02	C	Good
0.00	D	Average
-0.03	E	Fair
-0.07	F	Poor

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The last of the four factors that influence the performance rating is the "consistency of the operator." Unless the snapback method is used, or unless the observer is able to make and record successive subtractions as he goes along, the consistency of the operator must be evaluated as the study is being worked up. Elemental time values that repeat constantly would, of course, have a perfect consistency. This situation occurs very infrequently, as there always tends to be dispersion due to the many variables, such as material hardness, tool cutting edge, lubricant, ease of handling part, skill and effort of operator,

erroneous watch readings, and presence of foreign elements. Those elements that are mechanically controlled would, of course, have near perfect consistency values, but these elements are not rated.(9) Operators of high skill usually work more consistently than less skilled workers. At the same time, high effort tends to disturb consistency, particularly if the operator is not highly skilled. If, after all these factors have been taken into account, an element is judged to be unduly inconsistent, the reason for the inconsistency should be sought. Inconsistency usually indicates that there is something wrong with the operator or the operation, and it is better to discover the trouble and correct it than try to adjust for it by the application of a leveling factor. The factors for consistency are provided, however, to call attention to the necessity of reviewing consistency on every study made, and to allow the time-study man to adjust the performance level slightly up or down if, in his judgment, the consistency of the data indicates that it should be done.

There are six classes of consistency: perfect, excellent, good, average, fair and poor. Perfect consistency has been given the value of plus 4 per cent and poor consistency is rated minus 4 per cent, while the other categories fall in between these values.

Following is a table showing the different rating values for different degrees of consistency.

Table 8. Consistency.

(5)		
+0.04	A	Perfect
+0.03	B	Excellent
+0.01	C	Good
0.00	D	Average
-0.02	E	Fair
-0.04	F	Poor

Some companies regard the "condition" and "consistency" factors primarily as caution signals only. Condition is regarded as average in all cases and the recommendation is made that the cause of inconsistency should be determined and corrected rather than graded. No measure is suggested for the various grades since the extent of variation in elemental times from cycle to cycle will depend upon the nature of the element, the operator's attitude, and practice opportunity.

To illustrate the use of the four factors--skill, effort, condition, and consistency in arriving at a performance level--suppose a job is rated, C2 on skill, C1 on effort, D on condition and E on consistency.

Skill	C2	+ .03
Effort	C1	+ .05
Condition	D	.00
Consistency	E	<u>- .02</u>
	Algebraic sum	+ .06
	Performance factor	1.06(8)

The Westinghouse method of performance rating is adapted to the leveling of the entire study rather than elemental evaluation. This method would prove quite cumbersome if used to level each element as soon as it took place.

It should be noted that this technique limits the variation that can be compensated for. When an operator slows down to half speed, it is impossible to make adequate adjustment through the leveling factor to correct the actual time to normal time. Within limits of about plus or minus 25 per cent of normal, the trained observer can get consistent results utilizing the technique. It is helpful to utilize benchmark performances as a training and checking device, just as for the other methods of performance rating. The definitions lack objectivity in

themselves and, unless the various levels of performance can be demonstrated, there is a tendency toward inconsistency in interpretation of the various gradations. Westinghouse's rating scale ranges from 50 per cent to 138 per cent and was established by extensive study and analysis and on examining a large number of time studies, it was found that this range was ample for all but a very few cases.

Although the rating values were derived from extensive studies, it is not disclosed how these allocations were derived and even so they do not seem to possess a strong rational basis.(9)

Presgrave attacks this method of leveling primarily because skill is listed as a leveling element. He contends that skill is a matter of method, to be taken care of by motion analysis. He states: "Motion analysis and correction are not matters of leveling factors or of rating, but must be achieved by selection, by elimination and by adjustment. To rate for skill, to attempt to measure it and express it by a number, is a fault that all time study men acquire in some degree."

Gomberg states, "Presgrave is quite correct when he argues that one operator performs at a higher rate of productivity than another for one or both of two reasons:

1. He performs identical motions with greater rapidity.
2. He performs the operation in a different manner.

But taking the latter problem out of the field of time study merely transfers it to another field where its basic insolubility will still bedevil time study techniques.

Consistency and uniformity of performance are a basic part of skill. It seems somewhat unnecessary to divide them from skill as separate factors.

"It is unwise to place a ceiling on allowances for conditions. If they are bad, they should be corrected. If they cannot be corrected, then it is unnecessary to set up a range within which a correction factor must fall."(2)



## EFFORT RATING

In 1944, Ralph Presgrave introduced his book titled, 'The Dynamics of Time Study', on Effort Rating. As Presgrave explains, "The term has been selected because of its wide acceptability, and when time-study men speak of "effort," they have in mind relative production rates. However, the meaning of "effort" is confined to the concept of speed of movements and carries with it no connotation of the expenditure of energy, or of the effects of skill, even though skill in the broad sense is recognized as contributing to both method and speed of movement.

The fundamental training in effort rating is a simple process achieved in a matter of hours. The application of effort rating in time study is somewhat more difficult because of the variety of work encountered and because the method has limitations under certain conditions. Presgrave has established two familiar human activities as benchmarks for his system. These are:

A. Dealing 52 playing cards into 4 piles in 0.50 minutes. The dealing of cards is done with the cards in the left hand, the thumb advancing the top card each time, the right hand grasping the pre-positioned corner of the top card between its thumb and first finger, carrying it to the proper pile before releasing it, and then reversing the motion back to the pack. Four piles are formed by the dealing, one in front of the dealer and the other three at the other three corners of a one foot square.

B. Walking at 3 miles per hour, taking 27-inch steps, on level ground and carrying no load.

Based on this system the average worker, with incentive, can exceed standard by 30 per cent.

Walking at 3 miles per hour is used because this rate has been used for many years by certain engineers as expressing exactly the hypothetical pace of the average competent operator on daywork. It is an arbitrary point, but no matter how one views it, it will appear reasonable. Consequently, this is perhaps the best way to initiate the training. All that is needed is an assistant, a stop watch, and a measured space. Convenient distances are 44 feet if seconds are being used, 52.8 for decimal-minutes and 47.5 feet for decimal-hours. These permit the use of even standards of 10 seconds, 0.20 minute and 0.003 hour respectively.

There are those who do not believe that rating can be taught by observing walking, that there is no carry-over to other dissimilar activities. This is not entirely the case, but it is true that the ability to rate is strengthened by studying other operations. The main use of the walking method is to make clear the whole general idea of speed within a range, and of the essential difference between speed and method, or between effort and skill, even though in terms of the final results they are indistinguishable.

A further objection to using walking as a training method is the fact that variations in length of pace, arm-swing, etc., tend to confuse the would-be rater and prevent him from cross-checking his ratings as closely as seems desirable. Consequently it is well to supplement this basic training by experimentation with some activity that is not so subject to method variation.

It has been suggested in some cases that movies be made of different jobs at different speeds to train large groups and loops could be used at

varying speeds so that ratings could be checked more precisely. This, too, is a valuable adjunct to training but it has its limitations and can only be used with complete satisfaction on those operations in which speed changes do not of themselves force changes in method upon the normal operator. For instance, in walking, if a picture is taken at normal pace and then speeded up, 50 per cent for example, the resulting impression is very different from that which is gained by observing a person walking rapidly. In such a picture the walker seems to totter along with peculiar restricted motions of the legs and arms. Conversely, a picture of a rapid walk when slowed down gives an impression of floating along in positions that seem to defy the law of gravity. Undue retarding of the film also gives jerky and flickering motions that confuse the observer.

In films of card-dealing, although the motions of the hands do not appear to be unduly distorted by variations in projection speed, the cards themselves seem to behave strangely. If the film is run at slower speeds than the camera, the cards float down to the table. If it is run faster than the camera, the cards leap at the table as if they had some motive power of their own. In either case the effect is not conducive to accurate rating!"(10)

William Gomberg's principle objection to effort rating procedure is that it seems to place a premium upon just plain speed-up. He cites an instance where he had an opportunity to witness an application of the method by one of its leading exponents. The logic was sound, but the empirical results were disastrous. The Management Engineering Department of the International Ladies' Garment Workers' Union has on file a film of three operators all performing the same operation of sewing a dart in a brassiere. Operator A is rated at 84 per cent, Operator B at 100

per cent, and Operator C at 190 per cent. These figures reflect their comparative productivity as measured by a wink counter in the camera field. Operator C is using a slightly different method from Operators A and B. All attempts to teach A and B the same motion sequence used by Operator C are of no avail. In all likelihood this preference has a firm foundation in the individual differences basic to their respective make-ups. When an observer was asked to rate Operator C, he rated her at 110 per cent on the basis of the relative pace she was maintaining. The ratings for Operators A and B were very close to the true relative productivity figure. It is quite easy to see what the result of the application of this rating procedure would mean. Employees studied would of necessity be those whose motion pattern was the most productive. Inasmuch as it is speed alone that is being rated, and the overwhelming number of operators are those whose motion patterns are not perfect, the logical application of this method would leave most operators without any bonus under an incentive plan. If, on the other hand, it is decided not to await the one best method but to speed-rate existing methods, then every time a rate, as the result of some dexterous redesign of an operator's motion pattern, exceeds the pre-assigned range met by the speed rating procedure, the plant engineer must demand the right to reset the rate. The only sound basis upon which Presgrave's effort rating becomes a useful concept is the assumption that all people can be trained to use the identical motion pattern down to the last muscular reaction. Presgrave's dispute with Segur on this score, indicates his disbelief of this assumption. Under the circumstances the usefulness of effort rating must be confined to the very simplest type of repetitive operations, and even there it remains suspect.

Presgrave is well aware of these defects. He lists the following limitations to effort rating:

1. The difficulty of rating above or below a certain range of speed.
2. The difficulty of rating certain types of operations.
3. The problem of method.

The first limitation is a limitation of the rater's ability as the extreme of either range is reached. The second involves jobs, such as clipping garments sewn in a chain, which are purely a function of a worker's dexterity. Presgrave assures us that these jobs are becoming fewer and fewer as the process of mechanization and de-skilling continues. This is a highly tenuous assumption.

Barnes has performed some interesting work in an effort to determine to what extent a rater can be trained to estimate pure speed accurately. Although his results show that there was some improvement in the ability of time study men to rate walking accurately, he warns: "No claim is made that the result of a walking experiment is a true index of the overall ability of a man to set standards."

Under the circumstances, it is somewhat difficult to assess the distinctive value of the effort-rating technique. Certainly under the circumstances, factors other than speed must, in the last analysis, be resorted to.(2)

## PACE RATING

Pace rating is a term employed in some companies, notably the U.S. Steel Corporation, to describe the system of performance evaluation in use. This term should not be confused with the much better known "speed rating" or tempo system. Not too much is known about this system. While the technique incorporates most of the ideas of speed rating and effort rating, two other devices are used to assist the person doing the rating and to extend the scope of the application. Thus, it is recognized that all jobs are not performed at the same tempo, so that the pace or speed observed must be related to a concept of normal for the type of work involved. The time study man uses a number of concepts of normal, depending on the type of work being observed. For example, such effort operations as shoveling sand, coremaking, brick handling, walking, etc., have been clearly identified as to method and have been quantified as to normal rate of production. Where his work is limited to one type or a few, the standards or normals would be correspondingly limited.

In order to assist the time-study man in the acquisition of a set of concepts that is uniform for all time-study men, a series of benchmarks have been provided, in different types of work. These have been quantified in terms of specific rates of production. Thus walking on a smooth level surface, without load, at X miles per hour is one standard. This and other standards can be duplicated or viewed on a motion-picture screen and thereby provide an objective interpretation of the pace described. Rating is expressed as a performance percentage above, below, or at normal, and the ratio or factor is applied to the selected time for the element.

An attempt is made to minimize the effects of other variables by studying those operators who are judged to be adequately qualified and trained to do the job in question.(6)

### HUMMEL RATING SYSTEM

The Hummel rating system is a performance rating technique developed by J.O.P. Hummel, Professor of Industrial Engineering, The John Hopkins University. This method relies on two criteris in the determination of performance level. Here the term "tempo" has been assigned as a synonym for effort, and the word "effectiveness," as a term somewhat comparable to skill.

These terms are defined as follows: (1) "tempo" is the relative rate of performing work, or the speed of doing work; (2) "effectiveness" is the degree of co-ordination or the lack of false, unnecessary or non-productive movements.

Tempo ratings are made in terms of percentage: 100 per cent is considered as normal. Tempo ratings cover a range from .60 to 1.30 in increments of .05.

Effectiveness is rated as either superior, excellent, good, average, fair, or poor; the values of each of these categories are:

Table 9. Effectiveness ratings.

(9)

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Superior	+0.15
Excellent	+0.10
Good	+0.05
Average	0.00
Fair	-0.10
Poor	-0.20

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These characteristics are described as follows:

Superior, Operator works with very nearly perfect smoothness of movement and a co-ordination making full use of hands, arms and body.



Excellent. Operator works with a high degree of smoothness of movement and co-ordination.

Good. Operator works reasonably smoothly, unbalanced movements and hesitations are present occasionally but are not readily detected.

Average. Operator does not noticeably have excess or unbalanced movements or hesitations.

Fair. There are occasional unbalanced movements indicating unsatisfactory co-ordination. Occasional hesitations.

Poor. Movements of hands, feet or body are poorly co-ordinated. There are frequent hesitations.

In determining the performance factor using the tempo and effectiveness method, the analyst multiplies the tempo assigned value by the effectiveness value algebraically added to unity. For example, if a tempo value of 1.10 be assigned and an effectiveness rating of "good" be given, then the performance factor will be:

$$P = (1.10) (1.05) = 1.155$$

Thus, in this case, the operator would be performing 15.5 per cent faster than the time study analyst's concept of normal. This leveling technique has a spread of .48 to 1.495, or is based on a range of productivity of 1 to 3.12.(9)

## SHUMARD RATING SYSTEM

F. W. Shumard developed a performance rating method which is claimed to be used successfully in many plants. The speed of the operator only is rated in speeds from 40 to 100 as shown below:

Table 10. Speed ratings.

(7)

Rating	Speeds
100	Superfast
95	Fast plus
90	Fast
85	Fast minus
80	Excellent
75	Good plus
70	Good
65	Good minus
60	NORMAL
55	Fair plus
50	Fair
45	Fair minus
40	Poor

Thus, the leveling multiplier to convert the performance time of a "good plus" operator to that for a "normal" (60 rating) operator would be  $75/60 = 1.25$ . The normal time thus obtained would be 25 per cent

greater than the actual time taken by the "good plus" operator.

Shumard selected 60 as the normal, corresponding with the speed shown by the normal worker under standardized conditions, who is working at a brisk rate but without any financial or other incentive except that attending the hourly basis common to the average factory. He designates 80 as an excellent speed and one that the operator on an incentive basis would usually attain.(7)

Mundel, in his book, ridicules this system, quote, "...the use of loose arithmetic leading to the introduction of additional decimals makes the method look much more exact. Such procedures would be amusing if they were not in use."(8)

## SPEED RATING

The most widely used system of rating in this country is that of rating a single factor—operator speed or tempo. In this method, the observer measures the effectiveness of the operator against the conception of a normal man doing the same work, and then assigns a percentage to indicate the ratio of observed performance to normal performance. Particular emphasis is placed on the observer having complete knowledge of the job before taking the study.

It is well understood that there are wide differences in capacities and abilities of individuals in every activity of life. Even though there are individuals that can perform in a super-human demonstration for periods of time, these are truly considered rare as found by Wechsler in his studies. Wechsler, in his book, The Range of Human Capacities, found that the range of most physical and mental activities vary as 2 to 1, if the rare exceptions are excluded. That is, the best has roughly twice the capacity of the poorest. In one factory experiment, results showed the poorest operator produced 51 pieces per hour and the best operator produced 104 pieces per hour, or a ratio of 1 to 2.04. In another experiment the ratio came to 1 to 2.14.

Based on the ratio of 1 to 2 and assuming that output would be based on 60 units per hour for a standard performance equaling 100 per cent, in one study the range of production was found to be from 50 to 100 units per hour, in other words only 4% of the workers were below the standard of 60 units and 96% were producing above standard, thus enjoying incentive pay, and the average incentive output was 72 units, approximately. This

is the 60 point rating scale which will be discussed later.

There are several different rating scales (see table ahead) in general use in the speed rating system and undoubtedly a competent and well-trained time study analyst can obtain satisfactory results using any one of them. A recent survey shows that the percentage system has greatest use and the point system comes next.

A study of the four different rating scales may help to show the difference between these systems. Just as you can read temperature on both Fahrenheit and Centigrade thermometers although there is a difference in their scale, so you can rate operator speed whether you use percentage, points, or some other unit of measure.

Scale A - 100% equals normal performance. Normal performance (that is, normal speed, tempo, or pace) equals 100% on rating Scale A. When this scale is used, it is expected that the average incentive pace will fall in the range of 115 to 135%, and the average for the entire group will be around 125%. This means that those operators who turn out between 15 and 35% per day more than normal will earn 15 to 35% extra pay for this extra performance. It is also expected that an occasional person, perhaps one in a thousand, would work at a pace twice as fast as normal. His performance rating would thus be 200%, and consequently he would earn twice the hourly base rate.

Scale B - 60 points equals normal performance. This is scale B, which was mentioned previously and illustrates the point system, with 60 points equal to normal performance and with the average incentive pace around 70 to 80 points. This scale is similar to Scale A, 60 points being equal to 100% performance rating.

Scale C - 125% equals incentive performance. There are some time

study analysts who use the "average incentive pace" as their benchmark. One company has adopted 125% as the point at which they would like to have the average output fall. Therefore, they try to determine this point and set their "incentive time standard" at this point and then add 25% to their hourly base rate in computing the amount of earnings that a person should receive at this point. For example, instead of stating that the time standard is 1.00 minute per piece and the base rate is, say, \$2.40 per hour, giving a piece rate of 4 cents per piece, they would state that the expected incentive output is 75 pieces per hour and that, when the operator reaches this point, he would be paid \$3.00 per hour (which is, of course, at the rate of 4 cents per piece). Although this plan is perhaps as sound as any other, some people think it is not so easy to explain to the operators and that it has no advantage over a plan using Scale A.

Scale D - 100% equals incentive performance. A few organizations use a scale having 100% equal to "average incentive pace," and this point is usually set 25% above normal performance. Therefore 80% equals normal performance on this scale.

Relationships of the four rating scales are shown in the following table.

Table 11. Rating scale comparisons.

(1)

Scale A	Scale B	Scale C	Scale D
200	120	200	160
190		190	
180	110	180	
170		170	140
160	100	160	
150	90	150	120
140		140	
130	80	130	
120	70	125	100
110		120	
		110	
100	60	100	80
90		90	
80	50	80	
70		70	60
60	40	60	
50	30	50	40
40		40	
30	20	30	
20		20	20
10	10	10	
0	0	0	0
NORMAL 100%	NORMAL 60 POINTS	INCENTIVE 125%	INCENTIVE 100%

Scales A, C, and D in Per Cent  
Scale B in Points

The rating factor is applied to the selected time to give the normal time. Assume that in a particular operation of assembling an electric switch the operator gave a consistent performance throughout the entire cycle and throughout the entire study, and that the total selected time was 0.80 minute. With a performance rating factor for the study of 110%, the normal time would be as follows:

$$\text{Normal time} = (\text{observed time}) \times \frac{(\text{rating in per cent})}{100}$$

$$= 0.80 \times \frac{110}{100} = 0.88 \text{ minute.}$$

Walking and dealing cards is used as a benchmark to represent normal time in speed rating. To facilitate the training of time study analysts and to acquaint supervisors and foremen with time study techniques, motion picture film of different operations are made. The General Motors Corporation has made a set of eleven films, each containing a different sequence of body and arm motions commonly found in factory work. The operator in each of these films is shown working at ten different speeds from 75% to 150%, with 100% as the normal speed.

The Caterpillar Tractor Company has also developed a set of performance rating films of many different operations in their plants, as a part of an extensive motion and time study research program. Other companies have made community time study surveys so that each participating company will know the position of its performance standard with relation to the average for the community. A study of 100 companies shows that 63% use motion picture films as a means of checking the rating ability of their time study analysts. One such set of films that has received quite a lot of publicity is the one produced about



15 years ago by the Society for Advancement of Management (called the SAM films). The films consists of 24 typical manufacturing and clerical operations and each operation shows 5 levels of performance. To obtain the performance levels for all these operations, some 1200 time-study men from 181 companies were used. Many other criteria were used to arrive at the final working results. During the evaluation rating the time-study men in each case used the prevailing rating system of their respective companies.

The following table lists the nature of the 24 operations:

Table 12. S.A.M. film title identifications.

		(12)
Operation Designation	:	Operation Title
A		Deal cards
B		Transport marbles
C		Toss blocks
D		Dink tile squares
E		Fold gauze
F		Pack gaskets
G		Countersink
H		Kick press
I		Shear rubber tile
J		Form rug cups
K		Cut cork tubes
L		Deburr
M		Shovel sand
N		Stack cartons
O		Feed rolling mill
P		Tape boxes
Q		Seal cartons
R		Pack cans
S		Bolt flange
T		Fill radiator
U		Check tires
V		Collate papers
W		Staple papers
X		Tear bills

In a 1963 magazine article (3), Kerkhoven claims that in operations M (shovel-sand) and N (stack cartons) of the S.A.M. films are rated much

too low. These are 2.5 and 2.4 times respectively. Were a man to shovel wet sand at a performance level of .0465 minute, he will have moved the hurculean weight of 56 tons for an 8 hour working day. And for the man stacking cartons at a rating of .0415 minute, he will have moved a total of 220 tons per day. This is an unbelievable weight to lift. Kerkhoven expresses surprise that these errors had gone so long unnoticed. The logic for his argument is based on physiological studies.(3)

Mr. Gomberg and his union associates feel that the S.A.M. do not represent anything but a sales promotion to raise money for research purposes. In fact the Society has hitherto served, as one of its main purposes as a scholars forum where material presented before the audience was completely open to the criticism of the scientific community. Doctrines presented there either survived or fell depending upon the ability of their proponents to establish and defend the scientific validity of the rationale behind their recommendations. A review of the Society's literature fails to disclose the publication of any nonofficial material critical of the methods or findings of the investigation. As a result the American Federationist carried a special editorial denouncing the imposition upon workers of such a unilateral study. Walter Reuther, president of the C.I.O., in a special memo to his officers, denounced the study and warned union officers against accepting any of these benchmarks as arbitration guides in disputes over production standards.(2)

## PHYSIOLOGICAL EVALUATION OF PERFORMANCE LEVEL

Many studies have been made which show the relationship between physical work and the amount of oxygen consumed by the subject. More recently it has been found that the change in heart rate is also a reliable measure of muscular activity, and moreover it is much simpler to measure pulse rate than oxygen consumption. An ordinary stethoscope and stop watch can be used for measuring pulse rate, or a telemetering device can be used to make a continuous record of pulse rate without interfering with the activities of the subject in any way.

The procedure is to have the person work at his job for a specified period and then measure his pulse rate at the end of this period, and at the end of one, two, and three minutes after stopping work, while the subject sits still in a chair. It seems entirely possible that a normal or basic pulse rate can be determined, and then new jobs can be measured against this benchmark. For example, if an operator using a prescribed method worked for a ten minute period and turned out five pieces, the change in his heart rate (from resting state) would be an index of the effort required to do this particular job. Because of individual differences it would be necessary to have this operator perform one or more "benchmark" tasks in order to relate his heart rate to the standard or norm for the plant or industry.

The fact that an increasing number of people in various parts of the world are working on this problem would suggest that measurement of pulse rate may eventually take its place along with the other methods of measuring work. For very light work and for physical activities that

will not effect a change in pulse rate, the Latur "force platform" may prove to be a reliable measuring device.(1)

## SUMMARY AND CONCLUSION

In a recent survey by Barnes, to investigate time study practices among 100 companies, it was found that 73% of the companies used the 100% system, 15% used the point system, 6% used the Westinghouse system, and 3% used other systems. Three companies made no response.

Depending on company policy, time-study men will continue making judgment of operator performance. A substitute procedure that will eliminate this requirement is not yet available when stop-watch time study is used. Since the problem is going to be with us, the logical approach is to do the best possible job with the tools at hand. Further, the way these tools are used must be cautiously examined to assure that they are being employed to the very best advantage. Thorough indoctrination and training followed with a continuing program of checking progress is a "must" in order that the performance-rating technique may do the job that is required of it.

As is true of all procedures requiring the exercise of judgment, the simpler and more concise the plan, the easier it will be to use, and in general the more valid the results will be.

It must be remembered that in the final analysis all measuring instruments, no matter how accurate, are utilized inspite of their designated degree of error or tolerance. This being the case it seems incongruous that dissidents are not more receptive to judgmental performance techniques. Perhaps the reason for the difficulty of gaining full acceptance of judgmental leveling is that this is an era of highly sophisticated technical advancements with their precisional operations,

and as a result society has become too demanding.

Judgmental leveling is fruitful and its the best known system to date.

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EVALUATION OF INDUSTRIAL TECHNIQUES, MAINTENANCE AND  
IMPROVEMENTS OF PERFORMANCE RATING IN TIME STUDY

by

HENRY KIJOWSKI

B.S., Aeronautical Engr., Tri-State College, 1945  
B.S., Mechanical Engr., Tri-State College, 1947

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"To decide just how hard it is wise to make the daily task," was uttered some 60 years ago by the late Frederic Winslow Taylor. Today performance rating, still a subjective process, is still recognized as the best means of evaluating a worker's output or "normal pace." "Normal pace" is defined as the effective rate of performance of a conscientious, self-paced, qualified employee when working neither fast nor slow and giving due consideration to the physical, mental or visual requirements of the specific job. Therefore performance rating is that process during which the time study analyst compares the performance (speed or tempo) of the worker under observation with the observer's own concept of normal performance.

Training and maintaining analysts for peak rating abilities is done by comparing independent ratings of several analysts on the same job and/or using movie films of different jobs. The most notable rating film in use is the one by the Society for Advancement Management which is used by 75% of industry. As a basic benchmark to use for rating, dealing a deck of cards in .50 minute or walking at 3 miles per hour is extensively used.

Objective rating is a two step process: rating pace against a pace-standard and then a percentage adjustment for job difficulty based on tables. Ratings may still have errors, but this will be due to chance-cause effect and not bias. Similar to Objective rating is Synthetic leveling except observations are compared with certain standard data by as many elements of an operation as are available and from this the entire job is rated.

The Westinghouse System is claimed to be widely used and depends on rating four factors in the worker and that is skill, effort, conditions, and consistency. Many consider the descriptive terms too controversial.

Effort rating by Presgrave depends only on the benchmarks of dealing cards and walking. Principal objection to this system is the belief that rating cannot be taught by observing walking or dealing cards, that there is no carry-over to other dissimilar activities.

Pace Rating is similar to effort and speed rating and is principally used by U. S. Steel. Here the analyst uses a number of concepts of normal, depending on the type of work being observed.

The Hummel system and Shumard system are lesser known systems and are based in terms of percentage after first determining speed from Poor ..... Superfast.

Speed Rating is the most widely used system and only speed or tempo of the operator is judged on a 100% as a normal base. To facilitate training and maintaining analysts benchmarks for different speeds, many rating films are used, notably the S.A.M. films.

A survey reveals that, of 100 companies, 97 use judgment leveling and regardless of the leveling system used, results are being produced consistent with the variance of that system.